Buck Creek Flow Analysis

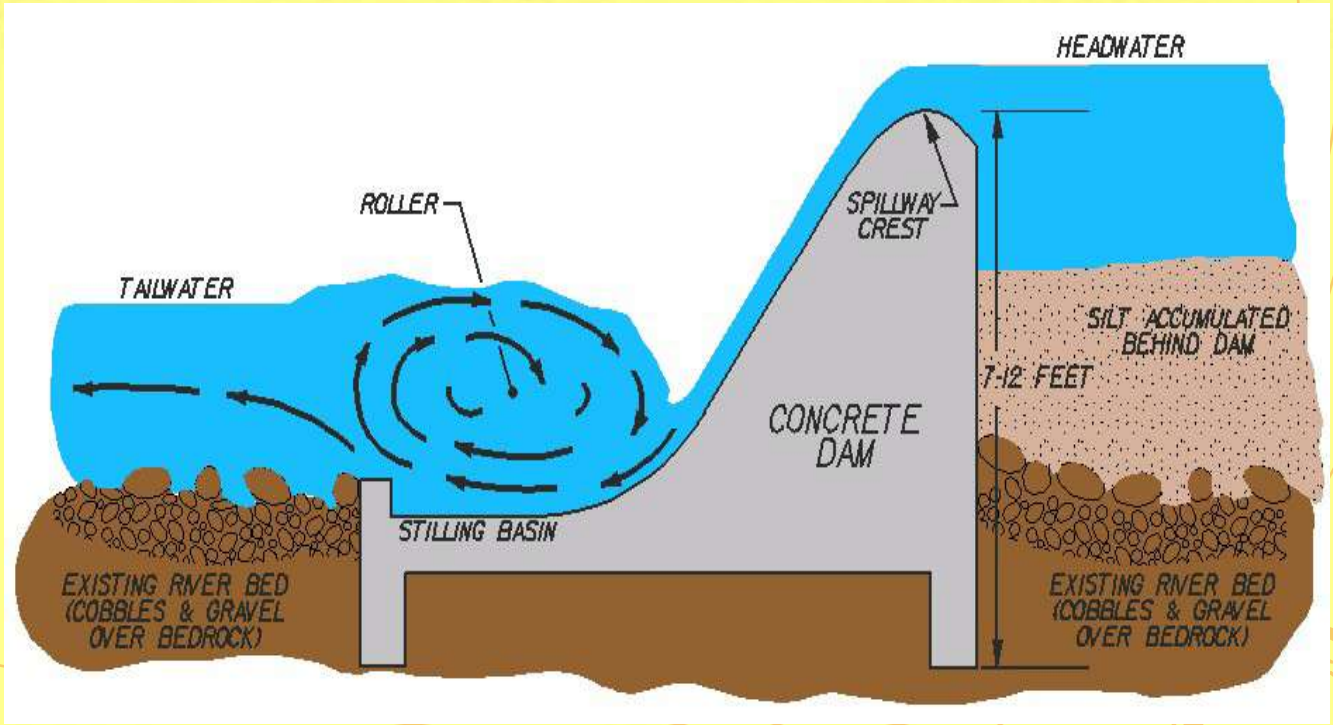
Andy Hoffman

Outline

- Introduction-Low head dam dangers
- Supercritical/Subcritical
- Froude Number-Hydraulic jumps
- Previous Work
- HEC-RAS
- Energy Equation
- Historical/Recent data
- Results
- Conclusion

Introduction

- Low head dam : small overflow dam used to alter the flow characteristics of a river or stream



- Dangers:
  - Drowning
  - Alter Ecosystem

Froude Number

- Froude Number→ $$Fr = \frac{U}{\sqrt{gh}}$$
- U = Velocity of flow
- g = Acceleration of gravity
- h = Depth of flow relative to the channel bottom
- $\sqrt{gh}$ = Wave velocity

Supercritical vs. Subcritical flow

- Is the Froude number > or < than 1?
  - Fr>1 = Supercritical
  - Fr<1 = Subcritical

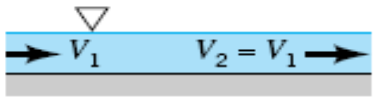
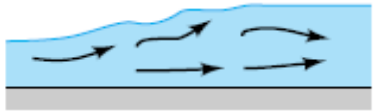
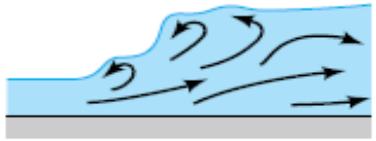
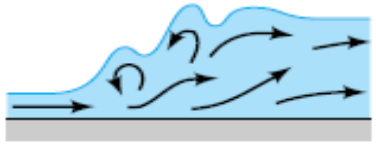
- Supercritical → When flow velocity is greater than wave velocity

- Hydraulic Jump→ Occurs when a flow at high velocity discharges into a zone that can't sustain that high velocity.

Hydraulic Jumps

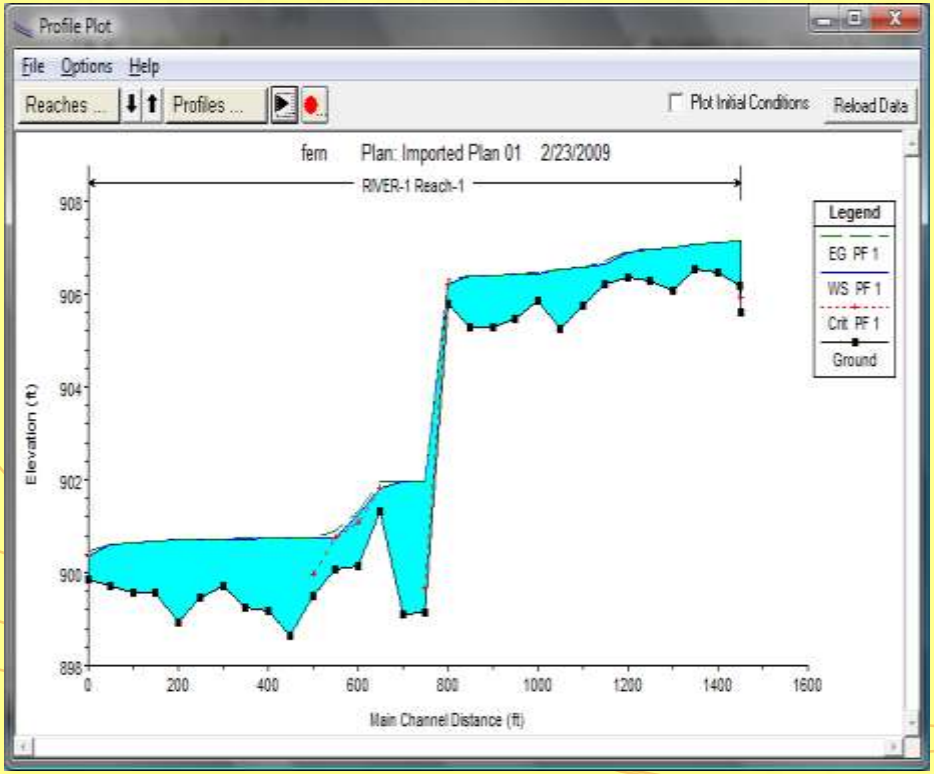
TABLE 10.3

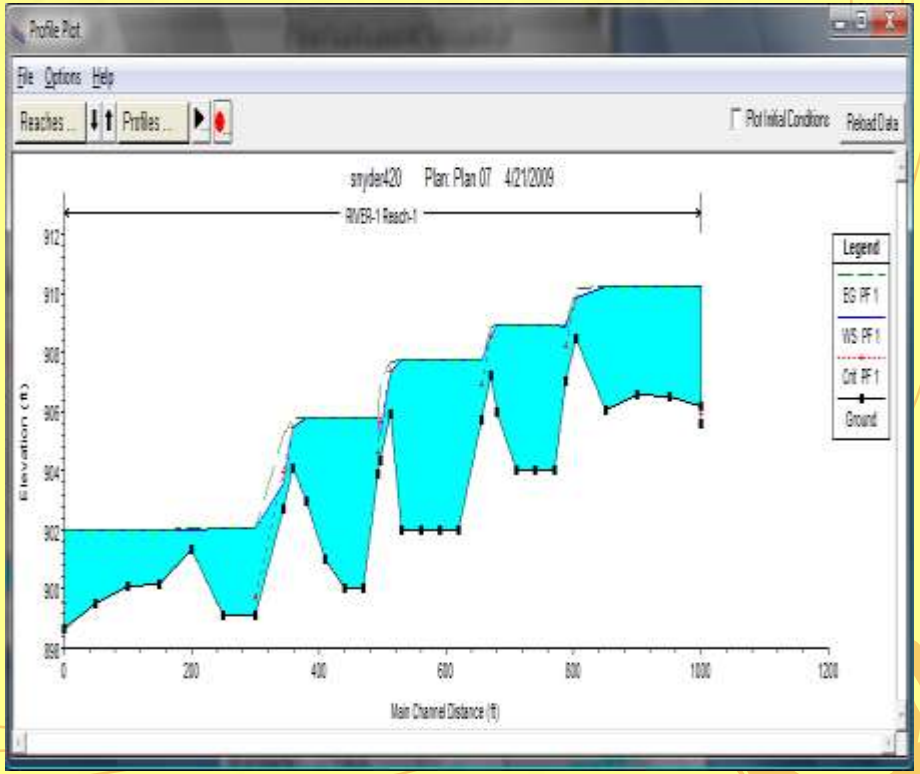
Classification of Hydraulic Jumps (Ref. 12)

Fr_1	y_2/y_1	Classification	Sketch
<1	1	Jump impossible	
1 to 1.7	1 to 2.0	Standing wave or undulant jump	
1.7 to 2.5	2.0 to 3.1	Weak jump	
2.5 to 4.5	3.1 to 5.9	Oscillating jump	
4.5 to 9.0	5.9 to 12	Stable, well-balanced steady jump; insensitive to downstream conditions	
>9.0	>12	Rough, somewhat intermittent strong jump	

Previous Work

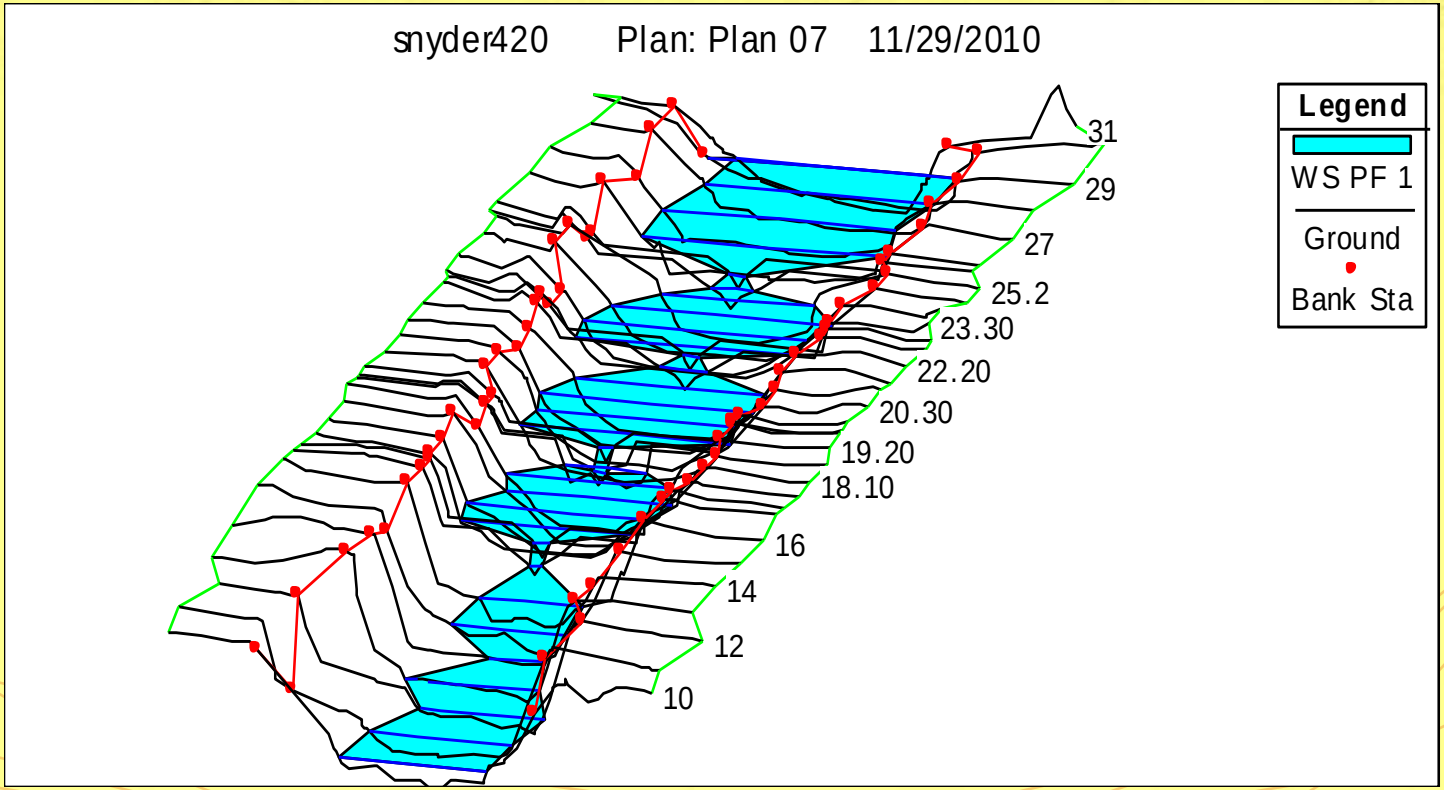
- Yasas Dhanapala's Project
  - Input Geometry and materials





My Uses of HEC-RAS

- Modeling and Simulation

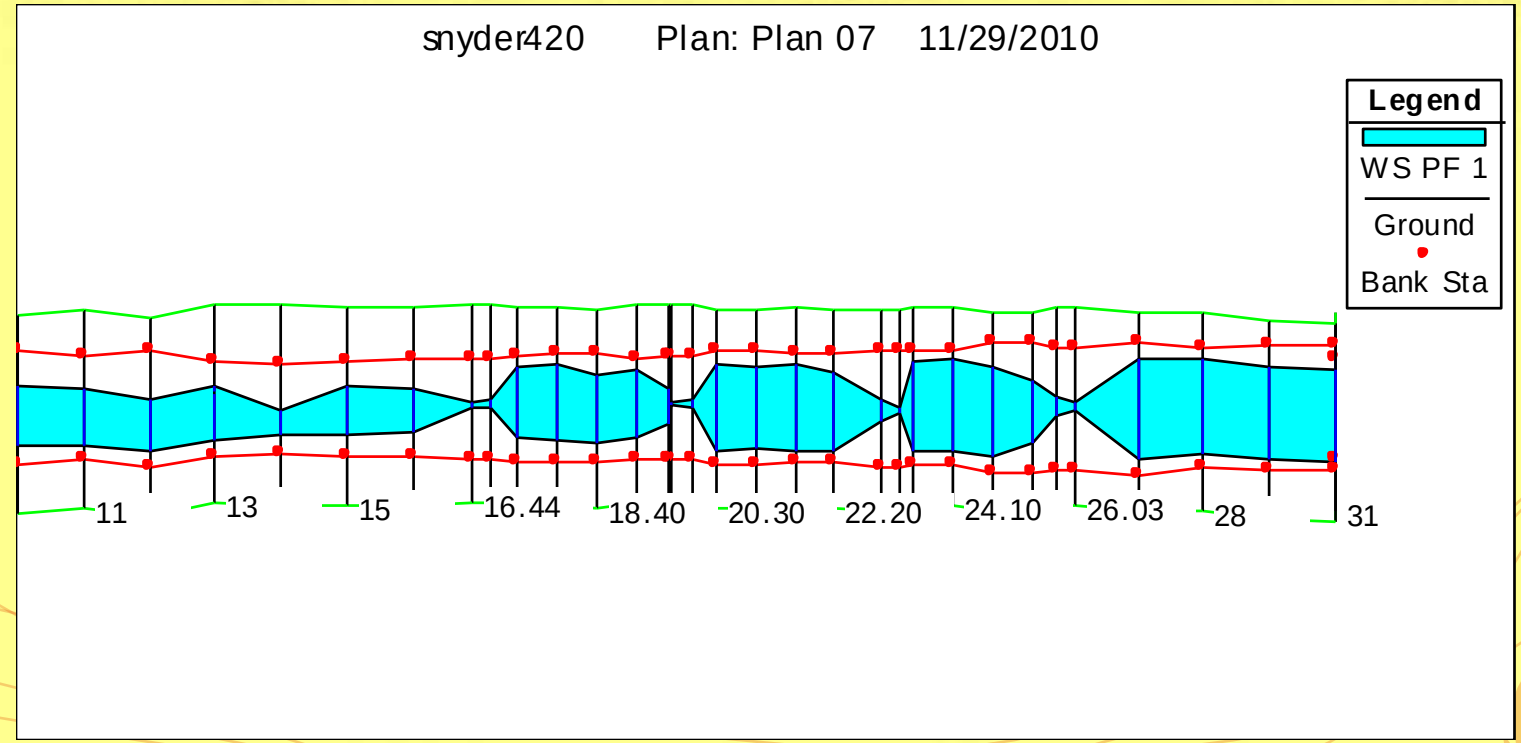


What is HEC-RAS?

- Hydrologic Engineering Center's River Analysis System
  - Steady/Unsteady flow hydraulics
  - Sediment transports/mobile bed compositions
  - Water temperature modeling

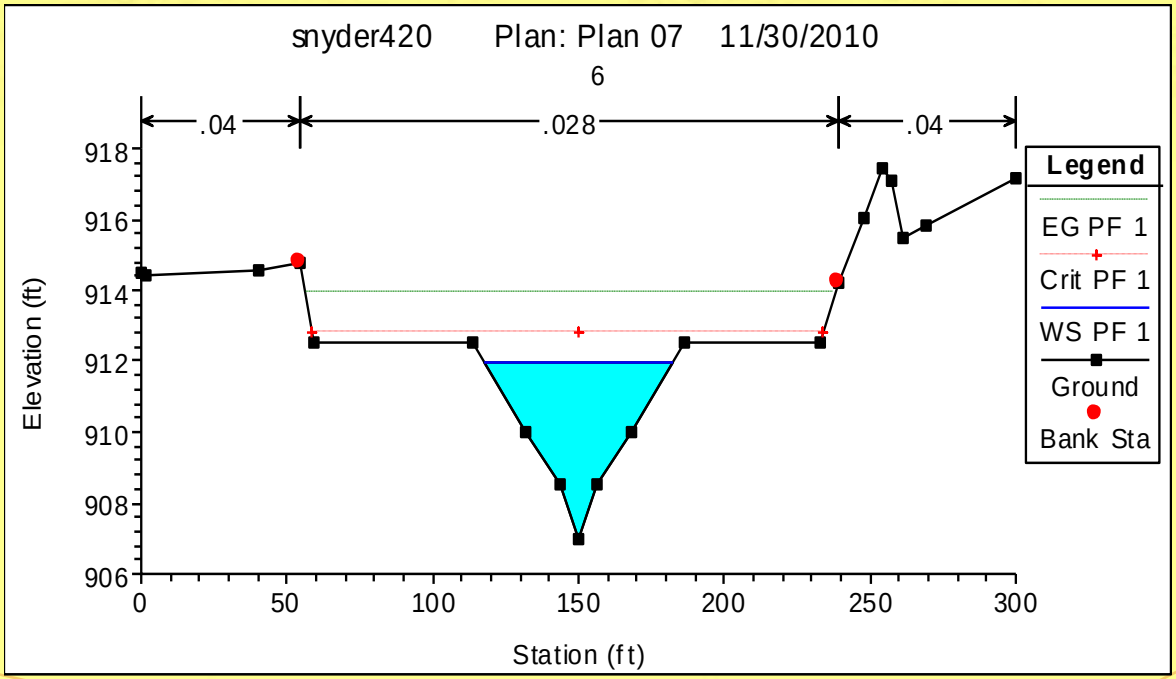
Cross Sectioning

- Considering steady flow
- Areas of interest/change



Cross Sections (cont.)

- Individual Cross Sections
  - Sectional water levels →Flooding



Energy Equation

$$Z_2 + Y_2 + \frac{a_2 {V_2}^2}{2g} = Z_1 + Y_1 + \frac{a_1 {V_1}^2}{2g} + h_e$$

- Z_1, Z_2 = Elevation of the main channel bottom
- Y_1, Y_2 = Depth of water at cross sections
- V_1, V_2 = Average velocities (Total discharge)
- a_1, a_2 = Velocity weighting coefficients
- h_e = Energy head loss
- g = Gravitational acceleration

Energy Diagram

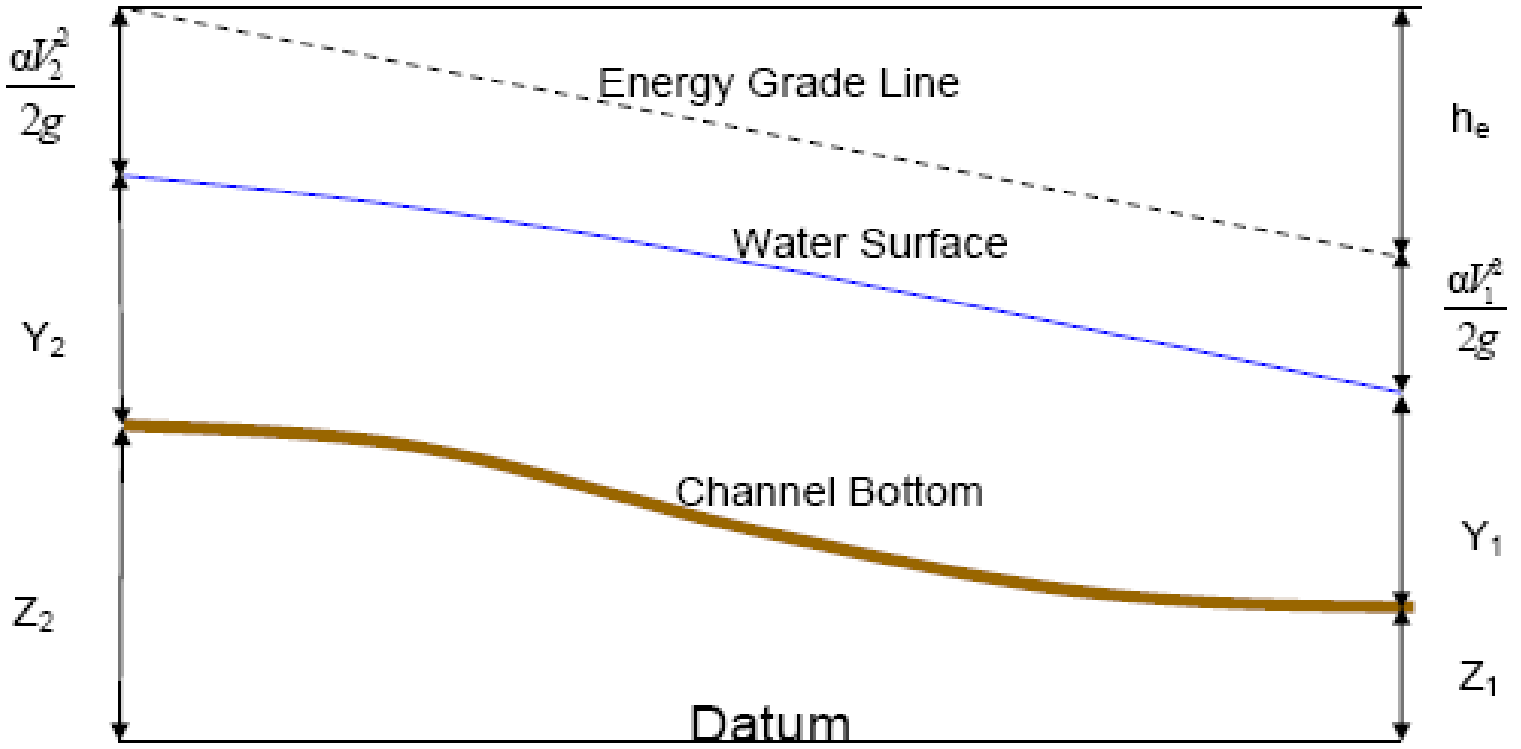
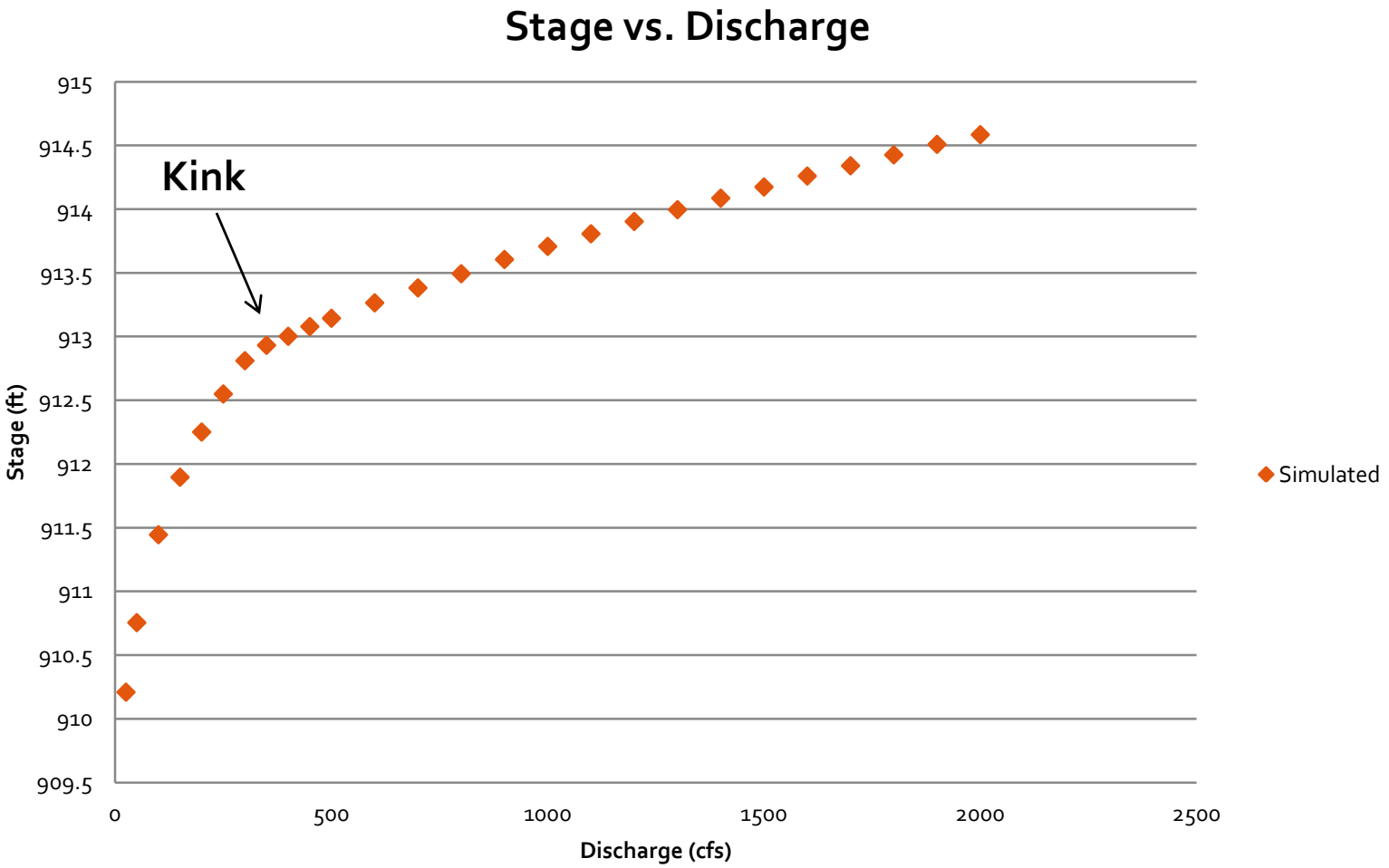


Figure 2-1 Representation of Terms in the Energy Equation

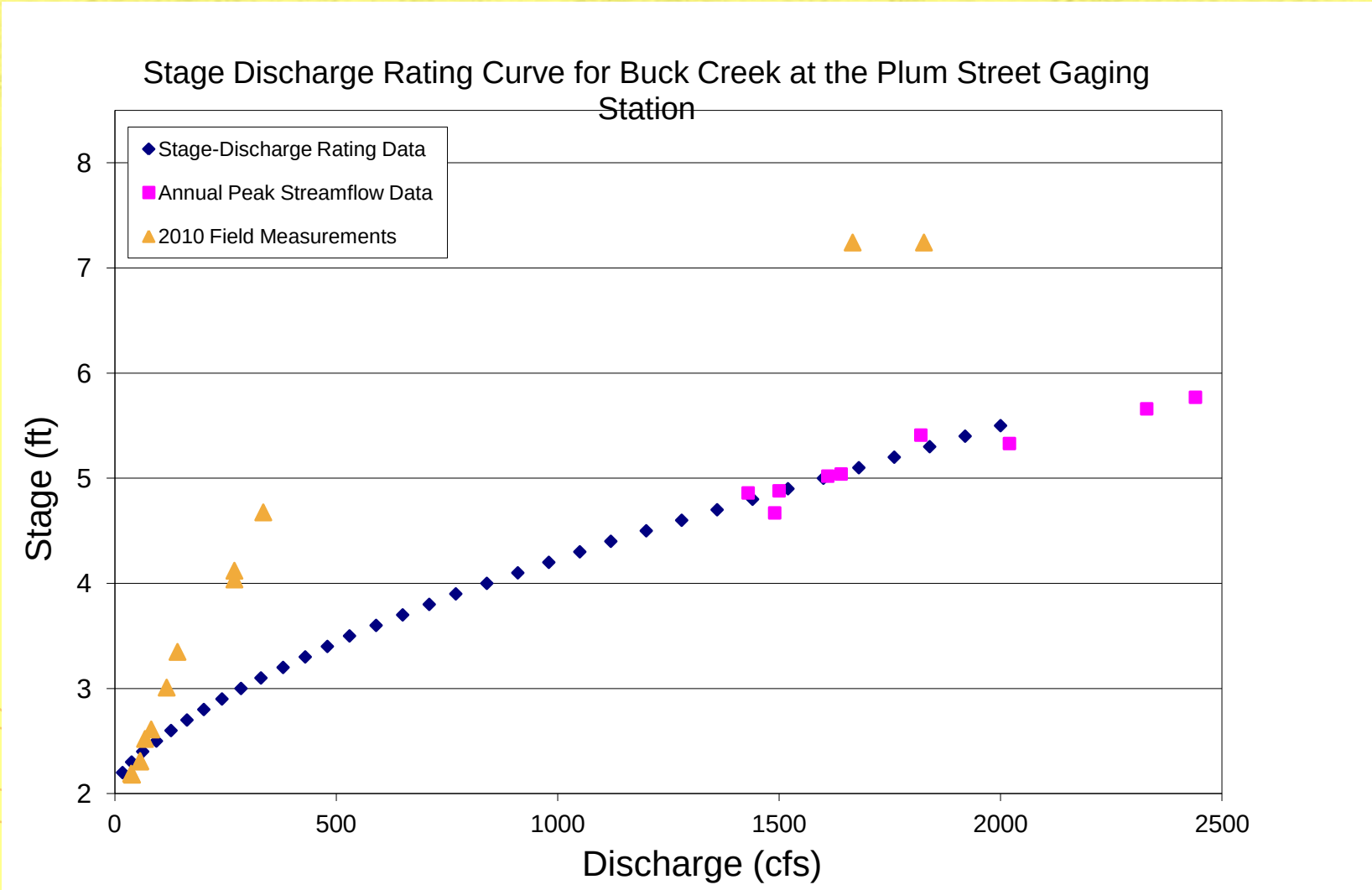
Results

- Modeled Stage vs. Discharge plot
  - Recent/Historical Data
- The "Kink"
- Froude # Profile Plots
  - Hydraulic Jumps

Results (cont.)

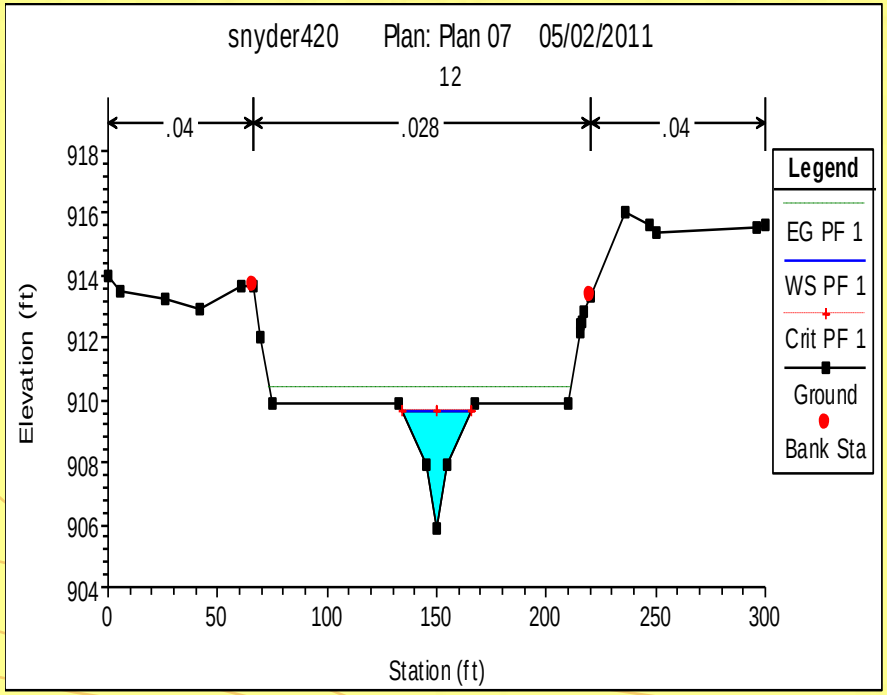


Recent Data (Scaled)

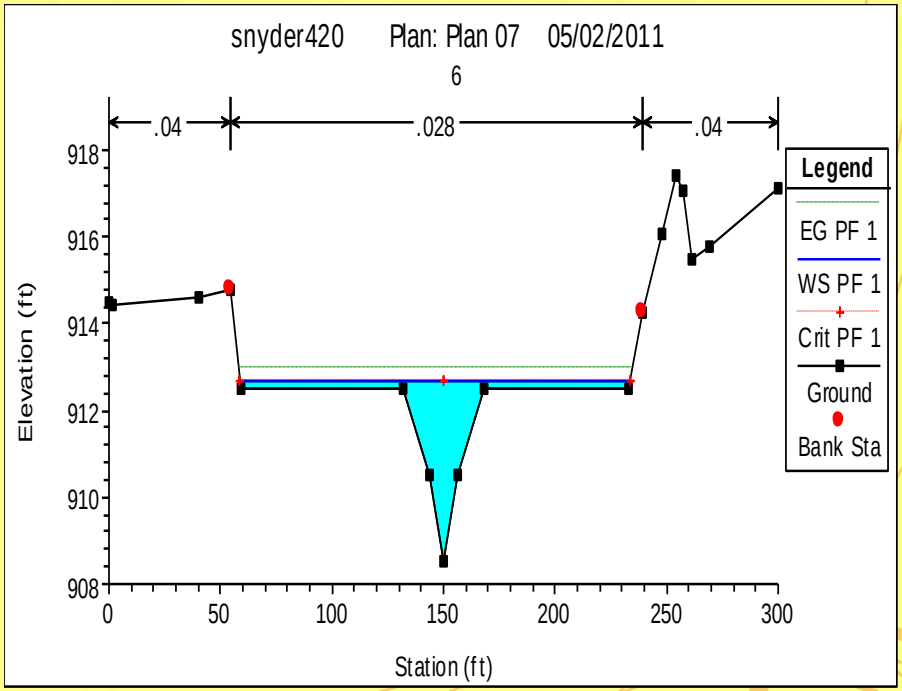


Verification

- The "kink" in the curve:
  - At about 350 cfs



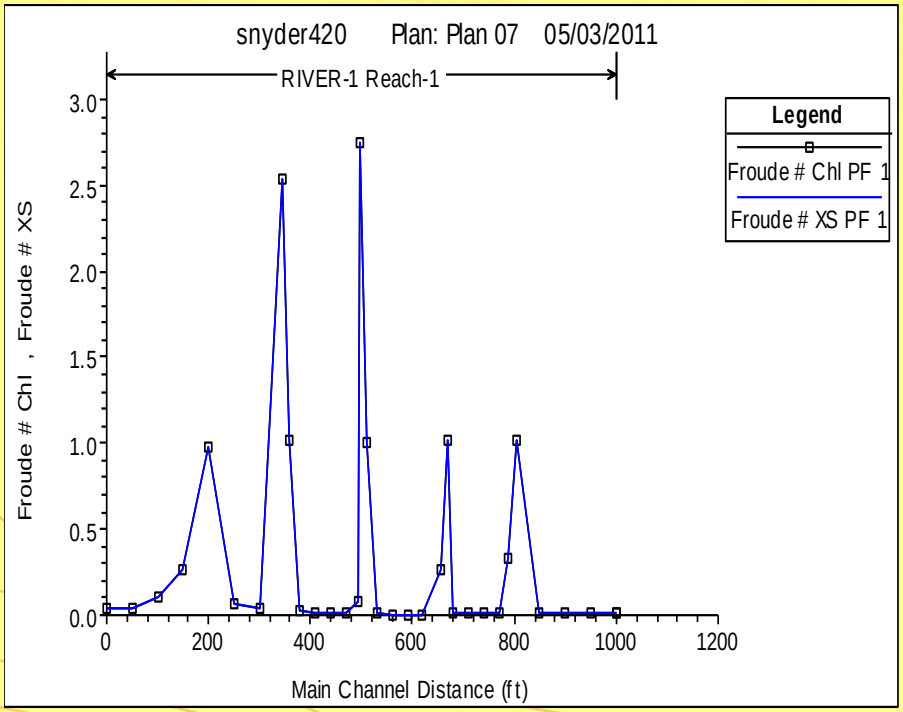
325 cfs



375 cfs

General Profile Plot

- Determine position of possible hydraulic jumps



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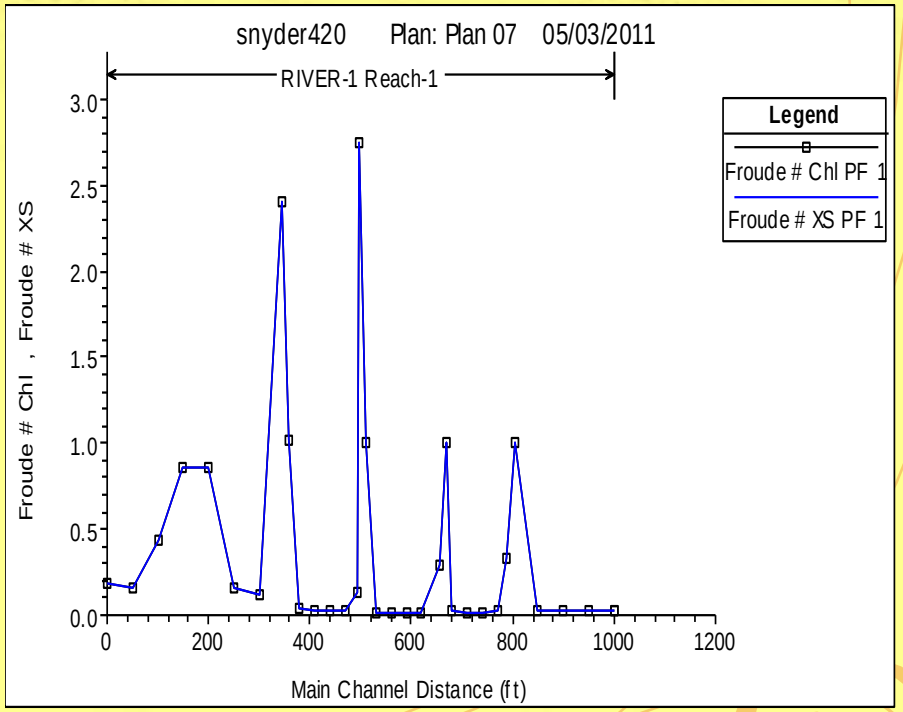
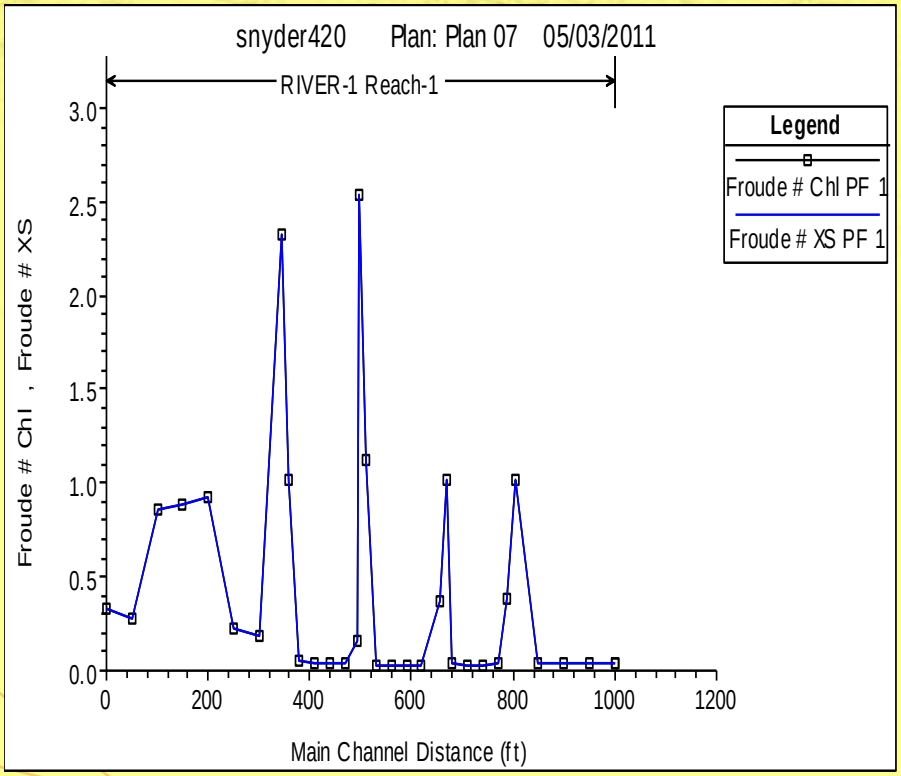


200 cfs

General Profile Plot (cont.)



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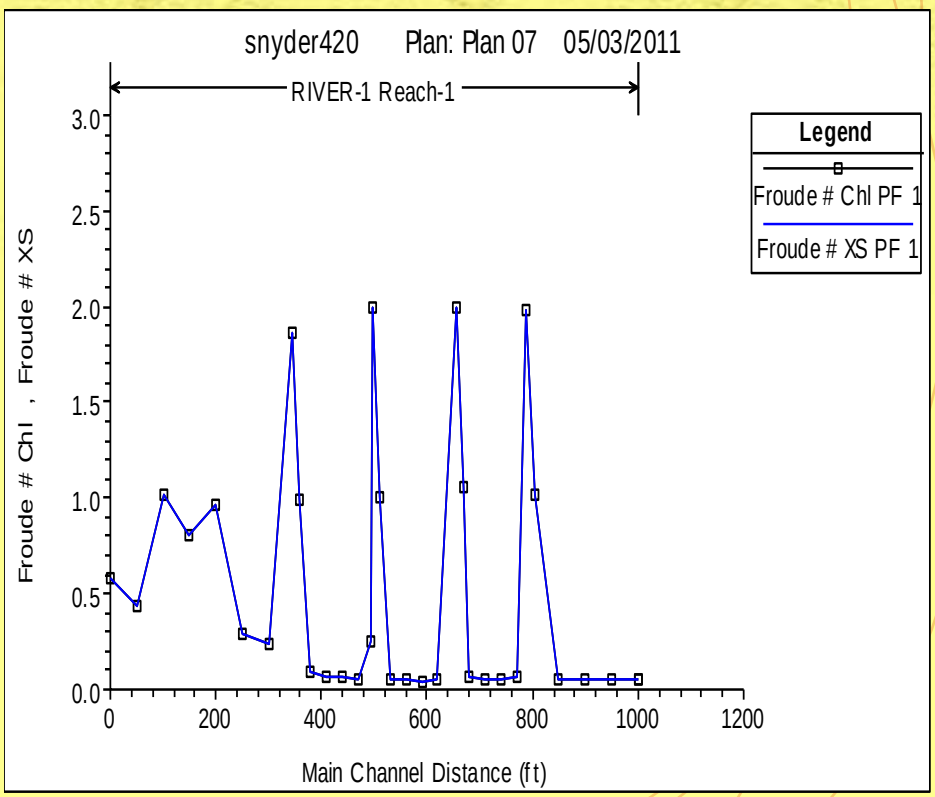

650 cfs

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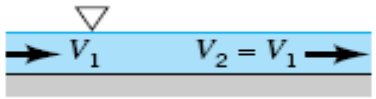
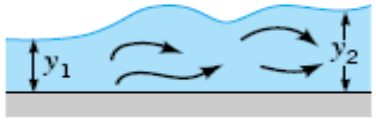
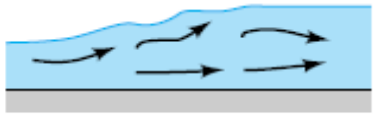
<1	1	Jump impossible	
1 to 1.7	1 to 2.0	Standing wave or undulant jump	
1.7 to 2.5	2.0 to 3.1	Weak jump	
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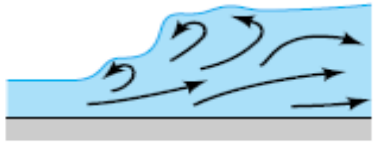
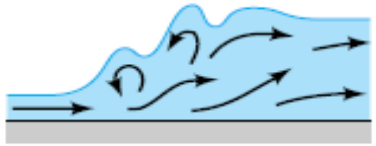
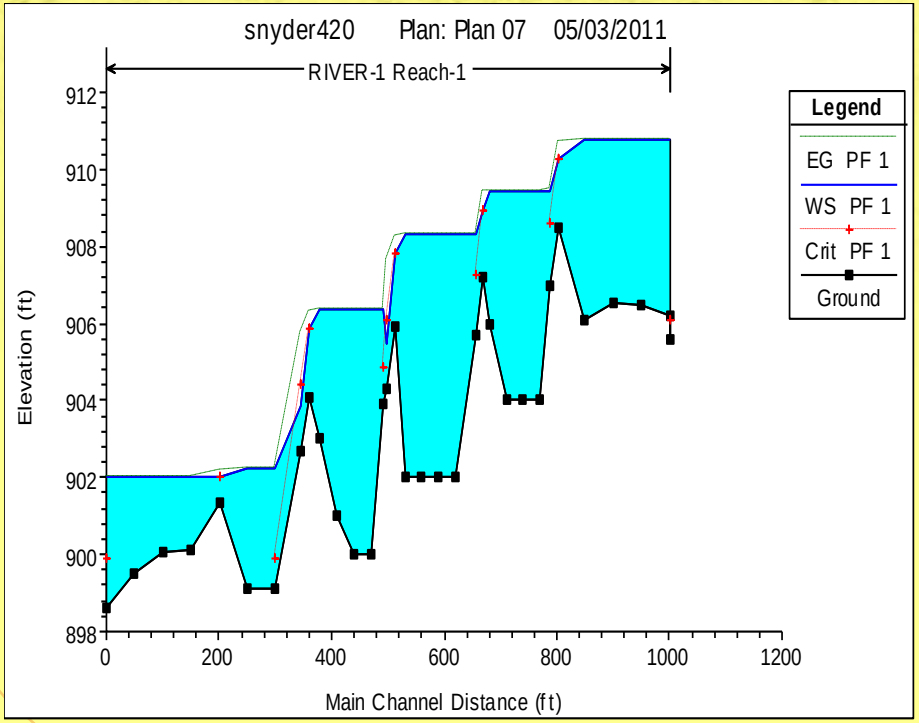
4.5 to 9.0	5.9 to 12	Stable, well-balanced steady jump; insensitive to downstream conditions	
>9.0	>12	Rough, somewhat intermittent strong jump	

Hydraulic Jumps (cont.)



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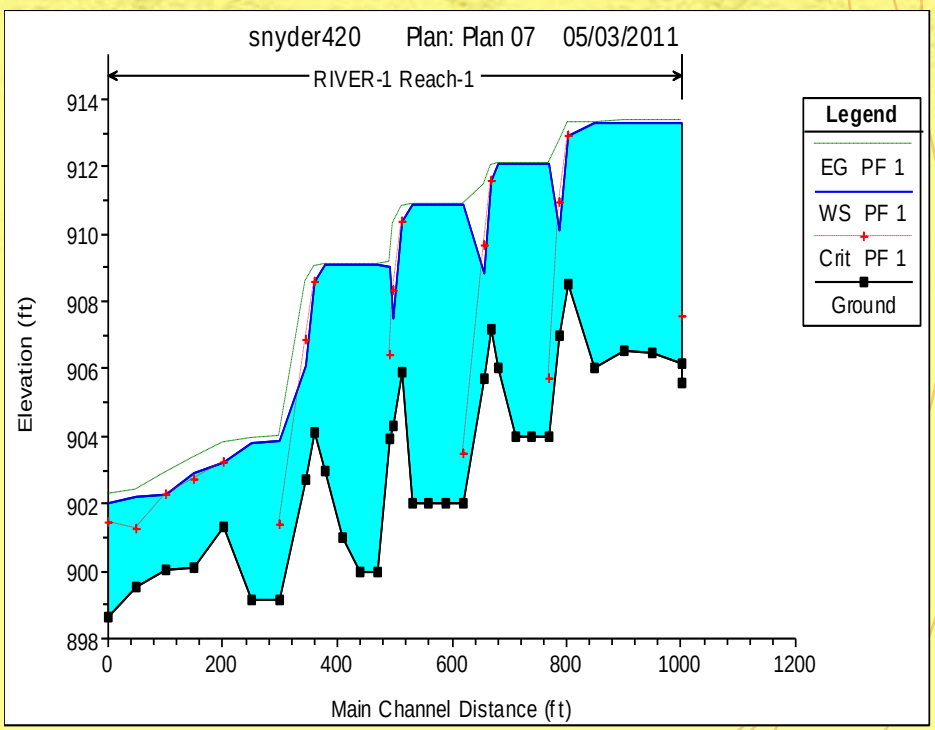

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Results (cont.)

- Using our model we are able to verify a curve of Buck Creek's Stage vs. Discharge.
- We are able to locate points of possible hydraulic jumps at any different flow rate.

Future Work

- Compare actual flow rates upstream vs. stage values to check future data collected by the Geology Department
- Use this curve to demonstrate Buck Creek's flow conditions online for recreational users.

Conclusion

- Using the existing model to obtain a group of curves to verify Buck Creek's conditions based upon its stage, our curve represents the actual data taken by the geology department.
- Continue creating interpolation curves of river stage vs. flow rate for historical reference.

Acknowledgements

- Elizabeth George, Wittenberg Department of Physics
- HEC-RAS 4.1 Reference Manual
- Fundamentals of Fluid Mechanics by Munson and Young

Questions?